Evaluation of the Urban Air Quality in Brazilian Midwest Region

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Abstract-**Air pollution has become an important issue in world. In Brazil, the recent development economic process allowed to the other regions of the country pass a diversification in the business matrix. The present study addresses the air quality in an urban area of Midwest Brazil, which proposes to initially produce a body of information related to air quality that until now is new to a region that suffers an accelerated industrial process. Tres Lagoas (47'S 20th, 51st 42'W) in eastern Mato Grosso do Sul (MS), represents the second largest GDP industrial of the state, and grows at an annual rate greater than the growth of Brazil, similar to the Asian countries. To understand the relationship between industrialization and consequences to the environment were evaluated air pollutants emissions from anthropic sources, meteorological parameters, and formation of secondary pollutants. Emissions of carbon monoxide are about 2,500 ton/year, and the local fleet of vehicles is the main source with a 97.2%. The industrial sector contributes with 46.4% of oxides of nitrogen. Concerning to the pollutants gases monitored in atmosphere, the mean concentrations, in the analyzed period (2005 and 2006), was measured in ppbv: O3 = 25 ± 14. 4, NOx = 9.4 ± 6,6 e CO=166. 5 ± 49.8. The Ozone, during September/2005, showed strong linear correlation with temperature (0, 76) and moderate to solar radiation (0, 58). Indeed, the results proved that the air quality levels of Tres Lagoas city is in accordance with the current Country legislation.**

Keywords-Air Quality; Atmospheric Pollution; Emission Inventory; Ozone; Urban Developing

I. INTRODUCTION

Since 1930’s, several studies have strongly increased the knowledge about the Earth atmosphere. Indeed, in the last thirty years, due to intense scientific and technological improvements a real progress happened in this area, including the effects of air pollution. [1-4]

However, the effects of air pollution, mainly around urban zones, still require a better understanding. In Brazil, large metropolitan areas like São Paulo and Rio de Janeiro have had already a good deal of research on their local atmosphere; they are among the regions where air quality is better monitored in country [3,5]. In other places, like Brazilian mid-west, such studies are modest or inexistent. Due to the factors such as geographical and economical ones, some regions of the country, like the city of Tres Lagoas (20o 47´S, 51o 42´W), east of Mato Grosso do Sul State, have undergone strong transformations in the last ten years. Potential sources of air pollutants and/or its precursors began to show up because of the installation of new industries (including a 240 MW power-plant), which has increased the vehicle fleet, the extensive conifer plantation for industrial use (biogenic hydrocarbons), a large hydropower reservoir (methane) and the seasonal occurrence of vegetation burning.

II. CHARACTERIZATION OF REGION

According to the Köppen model, the climate type of Tres Lagoas is classified as Aw, that is, warm and humid tropical, with rainy summer and dry winter. The average monthly temperatures range from 20 º C and 27 º C, with an annual average of 24 º C. [6].

The region topography consists of vast plains with slight variations. To the west of the city fluctuations are most evident, however without abrupt changes in altitude, presenting over a wide area oscillations around 100 m. In urban areas the average altitude is 319 meters. Terrain height data were obtained from NASA and edited in program specific computer, Global Mapper, to obtain an image whose reading was more needed, and subsequently utilized as input to simulate the dispersion of plumes of pollutants of anthropogenic origin.

From the Economic standpoint, Seplanct's second report [6], the city of Tres Lagoas between 1997 and 2004 underwent changes in weight percentages of its main economic activities. In 1997 just over 50% of local GDP was related to the sector trade and services, while 32.04% and 17.34% were from the sectors of industry and agriculture, respectively. Since then, investments in industry have been frequent and practically constant over the past ten years. The passage of the Bolivia-Brazil eased installation in 2001-2002, a Thermoelectric Plant to natural gas, which initially produced about 240 MW, but currently with funds from Program Accelerated Growth of Brazil (From Lula da Silva Government) capacity should reach 350 MW. See Figure 1, features of city terrain.

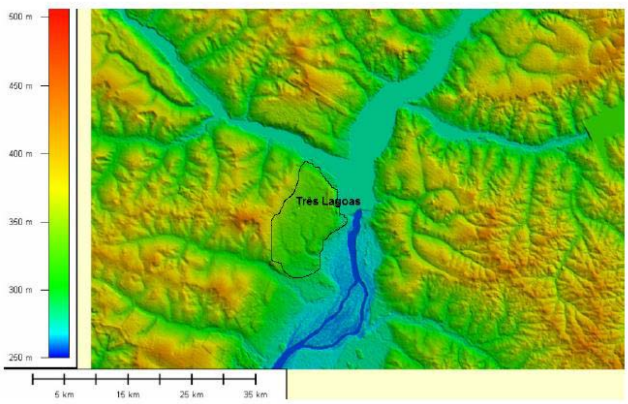

Fig. 1 City of Tres Lagoas, aspects of land

III. INVENTORY OF VEHICLE FLEET

The light vehicle fleet of Três Lagoas in the period of this research, 2005-2006, was nearly 20,000 units. Reflecting the national trend, the fleet of mopeds and motorcycles has been increasing, reaching the range 10,000 units in the county. Vehicle and motorcycles combined represent the major source of vehicular emissions. Heavy duty fleet emission, buses and trucks, was not considered in the inventory, for this fleet plays a greater level of activity on roads and not in the urban area.

According to [7] the Brazilian Institute of Geography and Statistics, 2008, between 2002 and 2005 the percentage of Mato Grosso do Sul State in GDP has remained almost steady, around 1.0%. In the same period, the percentage of the fleet in MS, comparing to the total fleet registered [8] in the Brazilian National Department of Transit (DENATRAN), and also compared to the evolution of sales by [9] National Association of Vehicle Manufacturers (ANFAVEA) has not significant variations, showing similar behaviour.

Vehicular Emission Inventory has the task of assisting the assessment of air quality, food databases for simulation of transportation and photochemical pollutants, guides decision making about aspects of vehicle traffic, observes effects of changes in fuels, and presents, depending on the scope of inventory, financial cost relatively low.[10-12]

Mathematical algorithm are applied to spreadsheets for estimating emissions of the pollutants CO, HC and NOx fleet circulating in the municipality of Tres Lagoas. Equation (1) is adapted from Murgel et.al (1987) and the reference report of the IPCC (1996).

$$E = FE.\ NV.\ KM \qquad (1)$$

Where FE is Emission Factor, NV is the Number of Vehicles and KM is total distance.

Below, in Table 1, it presented data from the inventory of atmospheric emissions for the fleet of Tres Lagoas.

TABLE I INVENTORY OF LIGHT VEHICLE FLEET EMISSIONS

	Total Emission of Gases (ton/year)			
	Gasoline	**Ethanol**	**Diesel**	**Motorcycle**
year	Carbon Monoxide (CO)			
2005	728,5	236,2	87,7/109,6	1663,5
2006	691,2	162,6	88,0/109,9	1604,0
	Hydrocarbon (HC)			
2005	83,0	28,2	26,6/31,3	345,3
2006	79,7	20,5	26,6/31,4	327,0
	Oxides of Nitrogen (NOx)			
2005	51,3	18,6	67,4/109,6	31,1
2006	49,5	15,0	67,5/109,9	33,3

In all classes of light duty fleet, the total emissions of carbon monoxide are higher than the others pollutants. The gasoline-powered vehicles were responsible for 728.5 tons of CO in 2005, and while these same cars for that year represented 45.6% of the evaluated cars fleet, their emissions did not reach 27.0%.

The motorcycles fleet, in 2005, about 9604 units, according to DETRAN-MS was lower than the fleet of cars, responsible for 61.3% (1663.5 tons) of total emissions of carbon monoxide. And, when hydrocarbons such percentage was even higher, 71.5% (345.3 tons) in the same year.

IV. INVENTORY OF THERMAL POWER PLANT

Another emission inventory developed from the bottom-up approach was the thermoelectric plant. The adoption of this approach is due to the collaboration of the company providing the emission data monitored continuously in the chimney of each generating unit. The emission calculations were performed hour-by-hour Excel spread sheet, considering the data from routine operation of gas turbines and thermodynamic conditions and geometry of the exhaust gases.

Figure 2 illustrates the monthly estimated emissions for the years 2005 and 2006.

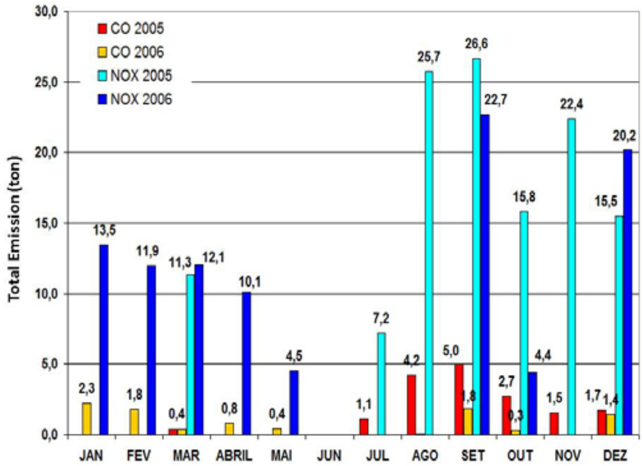

Fig. 2 Monthly discharge of pollutants gases from thermal power plant

In 2005, the Thermal Power Plant of Tres Lagoas operated in limited periods of time. Only two of the four generating units were operating in most of the time in which it operated, resulting in lower total emissions for that year. In 2005 the total emissions of Thermal accounted for CO and NOx approximately 16.7 and 124.6 tonnes respectively.

The months of August and September were those with the largest amounts of carbon monoxide and oxides of nitrogen discharged into the atmosphere. This discharge comprises about 42% of the annual emissions of NOx and CO 55.1%. This behaviour is not repeated in 2006, where 52.5% of NOx emissions and 61.8% CO occur between January and May. In August 2006 there is no record of thermal activity, but in September the NOx emissions were reduced by 14.7% over 2005.

In 2005, Thermal activity remained over 7 months, 6 of them in the second half, totaling 91% of NOx and CO of 97.6%. The following year, emissions were found in 8 months, and 5 in the first half, as a consequence of that the discharge of pollutants is distributed throughout the year, resulting in 47.5% of NOx and 39.1% of CO released in the second half, which represents about half of the 2005 emissions for this period. Figure 03 was obtained from the inventory calculations produced for this work illustrates the week in both years in which the thermal power plant showed higher activity.

Although during the second half of 2005 the Thermoelectric Plant has increased activity compared to 2006, the most intense periods of hourly emission levels of pollutants were in the second half of 2006, September and December. Between 17-23 September and 10-16 December, 2006, NOx emissions were responsible for half of all emissions monthly, with 9.5 and 10.2 tonnes respectively. In 2006, total emissions of carbon monoxide for Thermoelectric were lower, 9.2 tonnes, the same occurring with nitrogen dioxide estimated at 99.3 tons per year.

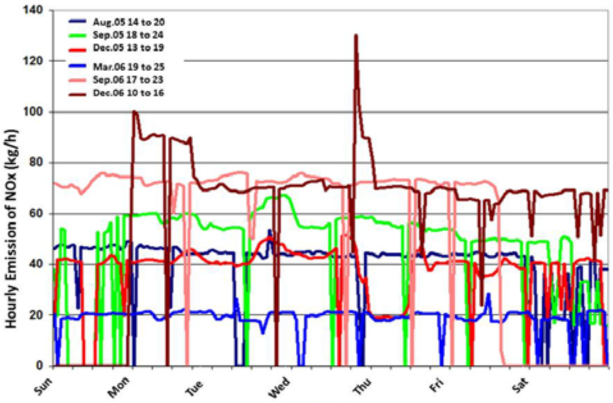

Fig. 3 Behaviour of Hourly Emissions from Thermal Power Plant

V. PRESENCE OF OZONE

Ozone, a secondary pollutant, results from chemical reactions in the atmosphere due to presence of NOx, hydrocarbons and sunlight [13-15]. The maximum acceptable ozone concentration level, recommended by CONAMA 03/90 (brazillian law), is 80 ppbv, and it could exceede just once a year. In 2005, the concentration registered reached 80 ppbv on October, 11th, at 1:30 pm. In 2006, the concentration of Ozone did not exceed the limit any time, But, between June and September, the concentration peak reached 4 times the threshold of 70 ppbv.

The annual average concentrations of ozone in 2005 and 2006 were, respectively, 25.1 ± 14.5 ppbv and 23.1 ± 13.0 ppbv, with a maximum of 80 and 71 ppbv. These results indicated that for the years covered by this study, the air quality standard, established by CONAMA 03/90, is met. They also indicate, according to [18,19], that the amplitude of ozone concentration for Três Lagoas meets the clean air conditions for the region.

The daily behavior of ozone is directly related to the presence of solar radiation (reaction activator) and, its precursors, such as NOx concentrations that occurs at dawn and sunset. Ozone overnight concentrations remain low and may have had slight increases due to transportation of layer immediately above the mixed layer. The maximum ozone concentrations were found during the afternoon, between 13 - 16 hours on most days.

Figures 4 and 5 illustrate the ozone behavior during 2005 and 2006 years.

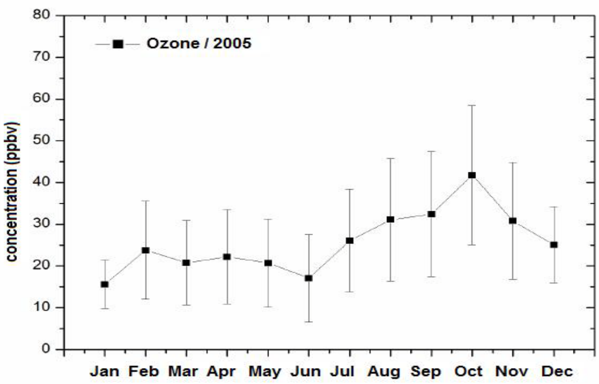

Fig. 4 Ozone average behaviour during 2005 year

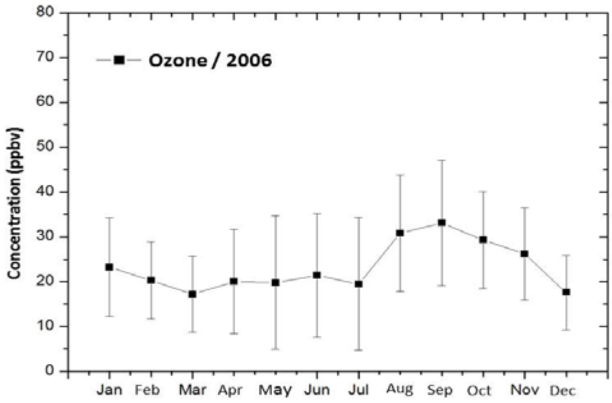

Fig. 5 Ozone average behaviour during 2006 year

In 2005 the periods from July to September and October to December, as in Figure 6, recorded the highest daily averages, keeping the non-linear behavior observed in the literature in general. However in 2006, the period from October to December, as in Figure 7, was significantly decreased to their average value. While in 2005 the highest average concentrations for the period from October to December, were close to 50 ppbv in 2006, these values were reduced to about 35 ppbv.

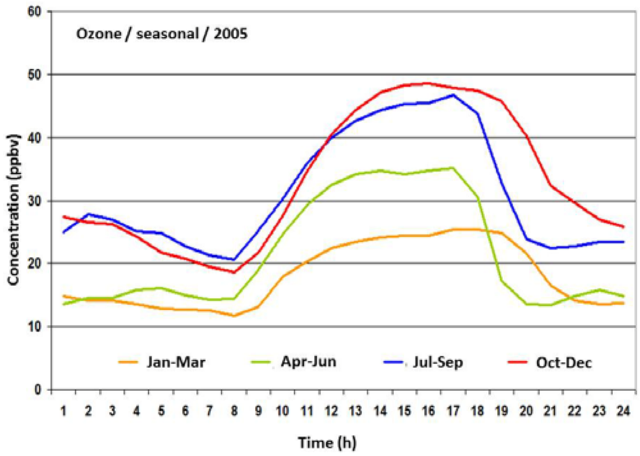

Fig. 6 Ozone average behaviour during seasonal periods in 2005

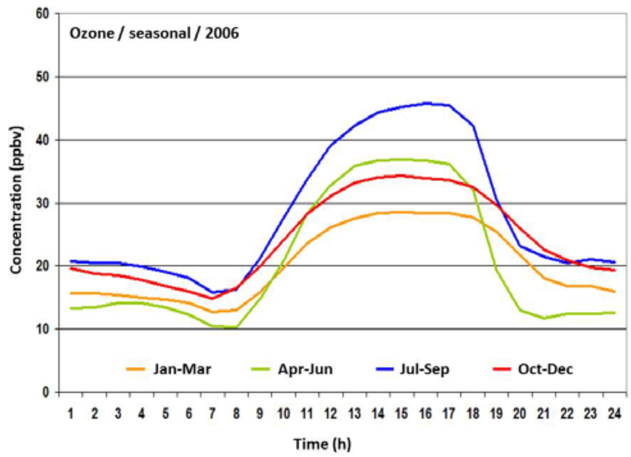

Fig. 7 Ozone average behaviour during seasonal periods in 2006

The results about the seasonal variation of ozone concentration curves also indicate that the lowest averages occur between the months from January to March, with a slight increase in 2006, but not exceeding the maximum average of 30 ppbv. Highlight needs to be given to the periods from January to March and from July to September, in which the curves of ozone can be compared with the activity level of thermal, due to these, periods also present more complete time series in all databases analyzed.

Table 2 reinforces the results of the mean concentration and standard deviation of ozone for the months of January, September, and October, presented in Figures 4 and 5. Another reason for choosing these months for a more thorough assessment is the fact that weather conditions offer different behaviors. In the second half of the literature, it indicates that influences the transport of pollutants from fires in the Amazon region and the Midwest, although not evaluated the fire is beyond the scope of this research.

TABLE III OZONE AVERAGE CONCENTRATION

Concentration (ppbv)		
	2005	**2006**
January	15,6 ± 5,8	23,2 ± 11,0
September	32,4 ± 15,0	33,0 ± 14,0
October	41,8 ± 16,8	29,2 ± 10,9

Comparatively, in 2005 and 2006 the values of the average concentrations of ozone, to September, are the same. However, the months of January and October showed between themselves and major differences from 2006, indicating increased formation of ozone in the second half of 2005, and more faint averages between the months of the first and second half of 2006. Variations in the seasonal behavior of ozone action may give indications to the sources external mechanisms present locally, however it is necessary for sample time series longer than two years to safely confirm the role of external agents, although local meteorological parameters, also can cause significant variations in the concentration of oxidant gases.

One of the main sources that contribute to the formation of ozone in the urban environment is the vehicle fleet. The evaluation of the weekly cycle of ozone, according to [16, 17], can reveal the source of this action. Figures 8 and 9 illustrate the results of time series of the weekly cycle with an annual average. The same is obtained from the calculation of the hourly averages considering all the years, organized according to each day of the week.

In Figure 8 the form of the curve average concentration of ozone doesn't indicate in such a way explicitly, a trend among the preferred day of the week and Sunday, for example, which usually has fewer moving vehicles as much load as the local fleet. On the other hand, Figure 9 displays for the day of the week, Sunday, Monday and Friday a slight difference in the maximum points, however, on average, this percentage is not more than 5%, and does not necessarily indicate a trend with in order that the standard deviation for the peak hours of sunlight throughout the year, is comparatively higher, about 30% of that percentage.

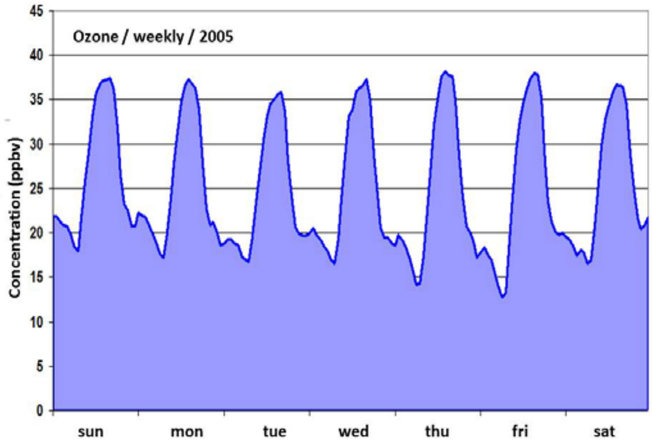

Fig. 8 Weekly average behaviour of Ozone during 2005

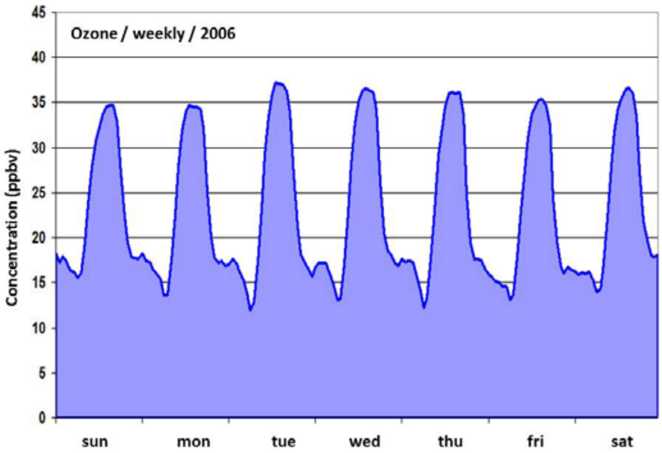

Fig. 9 Weekly average behaviour of Ozone during 2006

VI. METEOROLOGICAL PARAMETERS

The presence of pollutants in urban atmosphere can be enhanced (or mitigated), depending on prevailing conditions, the meteorological parameters as wind patterns, temperature and humidity. Data were obtained from two automatic monitoring stations owned by Petrobras SA and INMET.

Two of the most relevant meteorological parameters in the analysis of the variation in concentration of pollutants in urban atmosphere are the direction and wind speed. In Tres Lagoas the distribution of winds throughout the year meets all directions, but it is possible to define a predominant direction.

The data were processed and simulated in the computer program provided by WRPLOT Lakes Environment. The data were grouped into 16 different directions and evaluated for months, weeks, and years. The result for the predominance of the direction in which winds blow in both years, 2005 and 2006, indicates the West, with the resulting vectors in 265 ° and 273 °, respectively. As for the wind speed, it can reach between 3.6 and 5.7 m / s, but the percentages of participation of these speeds are low. The percentage of calm winds was higher in 2005 with 21.33% and was 8.34% in 2006. Figures 10 and 11 below illustrate the compass for the years 2005 and 2006.

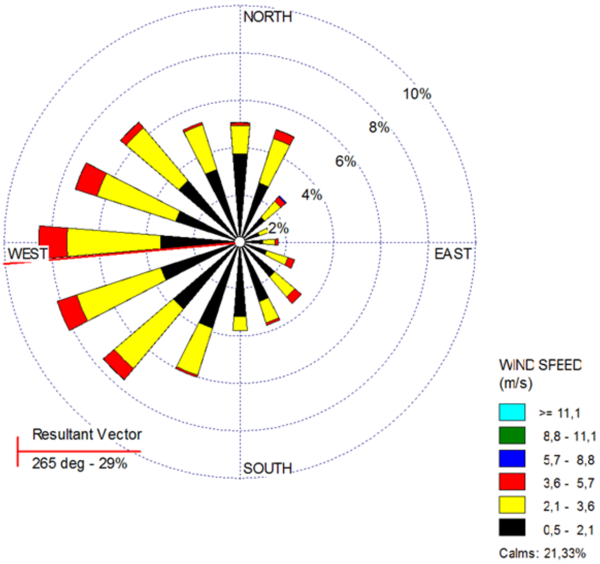

Fig. 10 Weekly average behaviour of Ozone during 2006

Statistical analysis was performed using the so-called principal component analysis, considering the time series of meteorological parameters of wind direction and speed, temperature, relative humidity, and radiation pollutants CO, NOx and O3. The collection periods 6-9 January and 1-4 September in 2005 were used to compose the correlation matrices. Tables 3 and 4 illustrate the arrays.

In both Tables 3 and 4, the strongest correlations between pollutants, NOx and CO occur with correlations with values of 0.89 and 0.90, as occurred with CO and NOx, it indicates in fact, a strong linear between the two pollutants, which suggests they possibly derive from the same source.

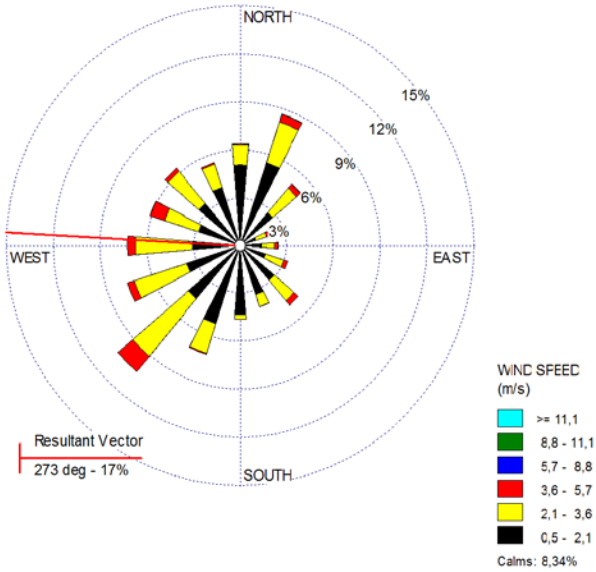

Fig. 11 Weekly average behaviour of Ozone during 2006

Both the CO and NOx average correlation remains strong with two other parameters in periods, the ozone concentration and wind speed, and inverse correlations were negative. This fact, combined with the strong linearity for each other CO and NOx and ozone concentrations remain at average levels up to 3 times less than the established by legislation (near rural levels) which seem to confirm the greater weight of the dynamics between pollutant sources and are related to local weather conditions.

TABLE IIII
MATRIX OF CORRELATION COEFFICIENTS

	Statistical Parameters							
	CO	**NOx**	**O3**	**D**	**V**	**T**	**U**	**R**
CO	1							
NOx	0,90	1						
O3	-0,65	-0,70	1					
D	0,26	0,26	-0,06	1				
V	-0,49	-0,54	0,59	-0,15	1			
T	-0,08	-0,11	0,50	0,19	0,32	1		
U	0,25	0,28	-0,65	-0,15	-0,43	-0,96	1	
R	-0,26	-0,16	0,39	0,17	0,28	0,54	-0,55	1

TABLE IVI
OZONE AVERAGE CONCENTRATION

	Statistical Parameters							
	CO	**NOx**	**O3**	**D**	**V**	**T**	**U**	**R**
CO	1							
NOx	0,89	1						
O3	-0,38	-0,54	1					
D	-0,07	0,02	-0,40	1				
V	-0,50	-0,66	0,28	-0,11	1			
T	0,19	-0,03	0,76	-0,35	0,02	1		
U	-0,09	-0,05	-0,67	0,28	0,31	-0,77	1	
R	-0,31	-0,38	0,58	-0,38	0,14	0,43	-0,56	1

VII. CONCLUSION

The research results were organized on atmospheric emissions inventories. It was also analyzed the pollutants concentrations and meteorological parameters. Among the emissions sources, the vehicle fleet turned to be the major source. It is responsible for 97% of carbon monoxide and 53% of nitrogen oxides of the total mass of pollutants released into local atmosphere. Concerning to the pollutants gases monitored, the mean concentrations, in the analyzed period (2005 and 2006), was measured in ppbv: O3 = 25 ± 14.4, NOx = 9.4 ± 6,6 e CO=166.5 ± 49.8. Statistical correlation between meteorological parameters and the pollutants concentration was also confirmed by others research results. The Ozone, during September of 2005, showed strong linear correlation with temperature (0, 76) and moderate to solar radiation (0, 58). The transportation analysis of biogenic hydrocarbon (Eucalyptus Forest) and NOx (Thermopower Plant) plume points to a supporting role of this source. Indeed, the results proved that the air quality level of Três Lagoas city is in accordance with the current Country legislation.

VIII. ACKNOWLEDGMENTS

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REFERENCES

[1] J. Haagen-Smit, “Chemistry and Physiology of Los Angeles Smog”, *Industrial and Engineering Chemistry*, Vol. 44, p. 1342-1346, 1952.

[2] J. Haagen-Smit, C.E. Bradley, M.M. Fox, “Ozone Formation in Photochemical Oxidation of Organic Substances”, *Industrial and Engineering Chemistry*, Vol. 45, p.2086-2089, 1953.

[3] E.M.Murgel et.al, “Inventário de Emissão Veicular – Metodologia de Cálculo”. *Engenharia Sanitária*, Vol. 26, p. 292-296, 1987.

[4] National Research Council, *Rethinking the Ozone Problem in Urban and Regional Air Pollution*, United States of America: National Academy Press, 1991.

[5] Diretoria de Engenharia Ambiental, “Comportamento Sazonal da Poluição do Ar em São Paulo – Análise de 14 Anos de Dados da RMSP e Cubatão, 1981 – 1994”, CETESB, SP, Relatório Técnico, 1996.

[6] (2008) The PMTL website [Online]. Available: http://www.treslagoas.ms.gov.br/

[7] (2008). The IBGE website [Online]. Available: http://www.ibge.gov.br/cidadesat/topwindow.htm?1

[8] (2006) The DENATRAN website [Online]. Available: http://www.denatran.gov.br/

[9] Anfavea, “Anuário da Indústria Automobilística Brasileira”, ANFAVEA, SP, CEDOC, 2007.

[10] J.M. Baldasano, and H. Power, *Air Pollution Emissions Inventory*, 1st, United Kingdom: Witpress, 1998.

[11] I.C.B. Campos et. al, “Simulation of Air Pollution from Móbile Source Emissions in the City of Rio de Janeiro”, *Journal Brazilian Chemistry Society*, Vol. 10, p. 203-208, 1999.

[12] J. L. Arriaga-Colina et. al, “Measurements of VOCs in Mexico City (1992-2001) and Evaluation of VOCs and CO in the Emissions Inventory”, *Atmospheric Environment*, Vol. 38, p.2523-2533, 2004.

[13] W.P.L. Carter, “Evaluation of Atmospheric Processes for Ozone Formation form Vehicle Emissions”, Report of Center for Environmental Research and Technology, 1994.

[14] B.J. Finlayson-Pitts, and J.N. Pitts, *Chemistry of the Upper and Lower Atmosphere*, 1st, United States of America: Acamedic Press, 2000.

[15] R. Atkinson. “Atmospheric Chemistry of VOCs and NOx”, *Atmospheric Environment*, Vol. 34, p.2063-2101, 2000.

[16] H. Mayer, “Air Pollution in Cities”, *Atmospheric Environment*, Vol. 33, p.4.029-4.037, 1999.

[17] J. Fenger, “Urban Air Quality”, *Atmospheric Environment*, Vol. 33, p.4877-4900, 1999.

[18] J. M. Wallace and P.V.Hobbs, *Atmospheric Science: An Introductory Survey*, 2nd, Canada: Academic Press, 2006.

[19] S.P. Arya, *Introduction to Micrometeorology*, 2nd, United Kingdom: Academic Press, 2001.

[20] Steering Committee, “Introduction to the Emission Inventory Improvement Program”, Morrisville, NC, EPA Energy Report, 1997.

[21] EPA – U.S. Environmental Protection, “AP42 – Wood Residue Combustion in Boilers”, Emission Factors Report, 2001.

[22] EPA – U.S. Environmental Protection, “Handbook for Criteria Pollutant Inventory Development: A Beginner´s Guide for Point and Area Sources”, Office of Air Quality, Basic Report, 1999.

[23] EPA – U.S. Environmental Protection, “User´s Manual for OZIPM-4 / PC version”, Office of Air Quality, User Guideline, 1989.

[24] EPA – U.S. Environmental Protection, “Procedures for Applying City-Specific EKMA”, Office of Air Quality, User Guideline, 1989.

[25] (1996) IPCC website [Online].Available: http://www.ipcc.ch/ipccreports/index.htm

[26] P.Artaxo et. al, “Formation of Secondary Organic Aerosols Through Photooxidation of Isoprene”, *Science Magazine*, Vol 303, p.1173-1176, 2004.

[27] Boian and V.W.J.H. Kirchhoff, “Surface ozone enhancements in the south of Brazil owing to large-scale air mass transport”, *Atmospheric Environment*, Vol. 39, p.6140-6146, 2005.

[28] T.B. Ryerson et. al, “Observations of Ozone Formation in Power Plant Plumes and Implications for Ozone Control Strategies”, *Science Magazine*, Vol. 292, p.719-723, 2001.